

Robotic lobectomies: when and why?

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Abstract: During the last decade, an abundance of papers has supported minimally invasive pulmonary resections (MIPR) *vs.* traditional open approach. Both video assisted thoracic surgery (VATS) and robotic thoracic surgery have shown better perioperative outcomes and equivalent oncologic results compared with thoracotomy, confirming the effectiveness of the MIPR. Despite the profound changes and improvements that have taken place throughout the years and the increasing use of robotic system worldwide, the controversy about the application of robotic surgery for lung resections is still open. Some authors wonder about the advantages of using a more expensive and more complex platform for thoracic surgery instead of the more established VATS technique. Robotic thoracic surgery represents, although the cumulative experience worldwide is still limited and evolving, a significant evolution over VATS, nonetheless several authors criticize the longer operative time and the high costs of robotic procedures. The aim of this paper is to answer two relevant questions: why and when the application of robotic technology in thoracic surgery is appropriate?

Keywords: Minimally invasive; robotic; lung cancer; lobectomy

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According to NCCN guidelines (version 5.2017) regarding non-small cell lung cancer (NSCLC) “*VATS or minimally invasive surgery (including robotic-assisted approaches) should be strongly considered for patients with no anatomic or surgical contraindications, as long as there is no compromise of standard oncologic and dissection principles of thoracic surgery*” (1).

Throughout the course of the last decade, the role of minimally invasive surgery in thoracic surgery has been increasing. Since 1992 when Lewis *et al.* (2) firstly reported the use of video-assisted surgery to perform lobectomies, many changes have occurred to the thoracic approach to make surgery less invasive. Although the clear benefits versus open approach (less trauma, pain, and shorter hospital stay), video assisted thoracic surgery (VATS) has some limitations for the surgeon: bidimensional vision, camera under assistant's control, long instruments in fixed ports, which create a fulcrum effect, and lack of tactile feedback.

Robot technology is an evolution of VATS, developed

to overcome the restrictions of manual videothoracoscopy, maintaining the advantages related to low invasiveness.

The robotic system consists of a master console used by the surgeon to manipulate the patient cart, connected via electrical cables and optic fibres with three instrumental arms and a camera arm. The surgeon's movements are transmitted to the cart manipulating master handles with a highly sensitive sensor able to filter physiologic hands tremor (6-Hz motion filter). The 3D high definition camera gives to the surgeon a much-improved vision compared to VATS and open approach. The robotic instruments, thanks to the seven degrees of freedom, allow the replication of the human wrist movement into the chest cavity. The three degrees of movement (pitch, yaw and insertion) are given by the cart arm; four degrees (internal pitch, internal yaw, rotation and grip) are guaranteed by the tip of the instrument, called in fact EndoWrist (3).

The da Vinci system® (Sunnyvale, CA, USA) is currently



Figure 1 Xi surgical cart positioning: laser crossair.



Figure 2 Patient position.

considered the only complete surgical system to perform thoracic surgery (4). During the years, four different generations of the robotic system have been developed (Standard, S, Si and Xi) with several improvements of the technological features, allowing feasible and safe surgical procedures.

The last platform, Da Vinci Xi, is an important evolution of the previous systems. Significant improvements are centered on the patient cart features and on the docking process. The patient cart is a mobile platform with a boom-mounted system, easier to move than the prior systems. On the boom, there is a laser crosshair facilitating the alignment of the patient cart with the camera port (*Figure 1*). The patient cart can be placed in any position around the patient. The camera is smaller than the one in the previous systems and fits into an 8 mm trocar, which allows a port-to-port change of position. The Xi platform has also a laser targeting system, which assists with the alignment of the cart to target anatomy and to limit the arms collisions, frequent in the previous systems. All Xi instruments have longer shafts and the distance between robotic arms can be less than in the Si (6 vs. 8 cm). The robotic arms have an additional joint (patient clearance) which allows rotating away and avoids the collision with the patient's body

or with the other arms. Da Vinci Xi is provided with robotic staplers that allows performing a totally robotic lung resection without external positioning stapler under bidimensional vision and which avoids traumatism during the manual staplers insertion through intercostal space.

Why?

Despite the profound changes and improvements that have taken place during the years and the increasing use of robotic system worldwide, the controversy about the application of RATS for lung resection is still open.

A drawback reported by most surgeons is the longer operating times: the robotic time to perform a lobectomy is averagely longer than that of an open or a VATS approach.

The average times reported by more experienced robotic surgeon are between 100 and 228 min (5-12). Anyway, the introduction of the Xi system has sensibly decreased the mean operative time of robotic procedures, thanks to shorter docking time and to technological improvements of the platform.

In our opinion, an important mean to decrease surgical time is the standardization of the surgical technique, firstly the port mapping: a mistake during this point could complicate the identification and the proper isolation of hilar structures with a longer operative time. Different authors describe several techniques in regard. Park *et al.* (13) described a three robotic arms technique with two thoracoscopic ports and a 4 cm utility incision. Gharagozloo *et al.* (6) reported a hybrid technique with three robotic arms, (positioned at the 8th, camera, 6th and 5th intercostal space), in this case the surgeon used a robotic approach for hilar structures dissection, then the platform was removed and he returned to the operating table to complete the operation. Louie *et al.* (11) and Anderson *et al.* (14) described a three-arm robotic lobectomy with a utility port; Jang *et al.* (15) used a utility incision at the fifth intercostal space. Ninan and Dylewski (16) reported a three arms technique using the same intercostal space for all ports (the 5th or 6th) and a utility port over the 11th rib. Veronesi *et al.* (7) and Cerfolio *et al.* (10) described four arms robotic lobectomy without utility incision.

At the Robotic Surgery Unit in Pisa we are currently using a four arms technique without utility incision. The patient is positioned in lateral decubitus, as for a posterior-lateral thoracotomy, with the operating table tilted at the tip of the scapula (*Figure 2*). When using Si platform the camera port (10 mm) is positioned in the 7th or 8th intercostal space



Figure 3 Xi port-mapping.

on the mid axillary line; the other ports (8 mm) are positioned in the 5th or 6th intercostal space on the anterior axillary line, in the 6th or 7th intercostal space on the posterior axillary line and in the auscultatory area. Recently, thanks to the introduction of the robotic staplers in the Xi platform, we have modified our port mapping. The posterior ports are positioned (when possible, depending on the chest dimension) along the same intercostal space (7–8th intercostal space) and in the auscultatory area (between the posterior rim of the scapula and the spine). The anterior port is positioned in the 5–6th intercostal space on the anterior axillary line, just over the diaphragm (*Figure 3*). Considering the variability of the chest dimensions, however, it is highly recommended to check the position of the port through the internal camera view, in order to perform the higher posterior access at the level of posterior inter-lobar fissure line. The Xi port mapping modification simplifies the stapler movements and allowing the positioning of all the posterior access in the same intercostal space, reducing postoperative pain. Thanks to our long experience with all the generations of robotic platforms, we have had the possibility to optimize the trocar position standardizing the procedure.

Currently, the instruments used during all major lung resections are: monopolar (e.g., Hook, Scissors) or bipolar instruments (e.g., Maryland) for dissection and graspers (e.g., Cadiere, Prograsp). The dissection of the hilar structures can be performed by the action of monopolar and/or bipolar instrument, while a grasper, inserted through the fourth arm, is used to retract the lung obtaining optimal exposition of the mediastinum. During the surgical procedure, CO₂ is insufflated (range, 5–8 mmHg) to drive the diaphragm down, enlarge the chest cavity and guarantee a good exposition of hilar structures.

Another aspect to take into account is the learning curve (the process of gaining experience and developing skills to make a procedure) of robotic surgery, some authors affirm that is shorter than that needed for traditional videothoracoscopic surgery. Gharagozloo *et al.* (6), Veronesi *et al.* (17) and Melfi *et al.* (18) suggested a learning curve of 20 robotic lobectomies for an experienced thoracic surgeon. Several studies suggest a wide range of cases (50 and 100/200) (19,20) to achieve a yield in VATS lobectomy. This difference between the Robotic and the VATS learning curves is likely to be due to the particular features of the robotic system that allow to perform the surgical procedures with the same approach and timing of the open surgery.

In our opinion it is mandatory to start the learning process with simple procedures such as for example, mediastinal lesions removal, and then to continue to more complex surgical interventions, such as lobectomies.

A further criticism raised against robotic surgery is the little data available about oncological radicality and survival with adequate follow-up period.

Indirect indicators of oncological radicality generally used are the number of lymph nodes resected and the lymph-nodal upstaging (the capacity to histopathologically identify metastatic lymph nodes clinically staged as negative), moreover, an adequate lymphadenectomy is essential to prevent under staging, with consequent lack of adjuvant treatment and worsening of prognosis. Nodal staging is therefore a surrogate of the quality of surgery. Two recent papers have shown a cutting point of 16 examined lymph nodes in the evaluation of the quality of LN examination or prognostic stratification postoperatively for patients with declared node-negative disease (21,22).

Discordant data exists on the radicality of nodal harvest during VATS lobectomies, more frequently, in fact, a lower median number of dissected lymph nodes are found and fewer nodal upstaging, particularly for the N2 group, when compared to open surgery (23–25).

Several authors reported their experience on analysis of lymph nodal upstaging in VATS procedures and thoracotomy resections, in most of the cases the studies reported a lower rate of upstaging in VATS group. D'Amico evaluated 189 patients underwent open lobectomy and 199 VATS lobectomy and observed different upstaging to N1/N2 between the two groups: 14.5% cases in the open group and 8.8% in VATS one (26). Also, Licht analysing 1,513 lobectomies for clinical stage I NSCLC performed by VATS or open surgery, confirms lower upstaging in VATS

group than thoracotomy group (11.9% *vs.* 24.6%), although the mean number of dissected lymph nodes stations were similar and no difference in survival was showed between two groups (27).

Boffa and colleagues conversely in a report of 11,500 anatomic lung cancer resection from the Society of Thoracic Surgeon database showed a similar lymph nodal upstaging after VATS and open surgery (11.6% *vs.* 14.3%) (28).

Comparing lymph nodal dissection by VATS versus open surgery a critical aspect is the evidence of superior number of mediastinal nodes removed during thoracotomy procedures, probably due to the greater difficulty to reach comfortably all mediastinal areas with thoracoscopic instruments (29).

The dissimilar results between VATS and thoracotomy lymphadenectomy in comparative studies are probably related with different expertise and level of skills of the surgeons.

Conversely, several studies have demonstrated the equivalence between robotic and open nodal dissection. According to these studies, the median number of lymph nodes resected with robotic approach is the same of open surgeries (17,30).

In our opinion, the robotic approach gives also a better dissection than VATS in a confined space of enlarged N1 lymph nodes and a more precise N2 lymph nodes removal.

Wilson reported the first experience of upstaging in patients with clinical stage I NSCLC who underwent robotic lobectomies. In this study upstaging was observed in 10.9% of cases, especially in patients with larger lung tumor (31). Park reports a 21% rate of nodal upstaging (6,32) and Velez-Cubian *et al.* a 30% of overall upstaging rate (33).

Despite the controversy over lymphadenectomy data, the long term survival and disease free survival are similar in NSCLC treated by VATS and open surgery, confirming the effectiveness of the mini-invasive procedure (29,31,34,35). The outcomes oncologic results in robotic treatment for lung cancer are more recent than VATS, not many large studies on long-terms outcomes have been reported. Park shows an overall 5-year survival of 80% (32), Wilson a 2-year overall survival of 87.6% with a DFS of 70.2% (31) and Melfi a 5-year actuarial survival of 80% (36).

However, the most criticized aspect is represented by costs of robotic platforms. Several studies have been carried out to compare the costs of VATS, thoracotomy and Robotic procedures. In 2008, Park and Flores (37) conducted a retrospective review to determine the expenses associated with the resultant hospital stay. The authors found robotic procedures less expensive than thoracotomy

(\$4,380 *vs.* \$8,368), but more costly than VATS (\$1,479).

Cost control is a fundamental aspect for a healthcare system, and for this very reason in Pisa was created a multidisciplinary robotic centre. In order to minimize costs, the managerial strategy of our centre is based on high surgical volumes, complex procedures and standardization of the technique. After 6 years of experience, with the increasing number of the robotic procedures and thanks to the standardization of the technique (prefixed instruments, shorter docking time, dedicated team of surgeons, anaesthetists and scrub nurses) the centre has obtained a positive result: robotic surgery has been actually considered revenues from disease-related-groups (DRGs) (38).

When?

With regard to the indications of the robotic approach, we noticed that in the majority of cases robotic lung resection is offered to very selected patients, with early clinical stages (I and II) and no comorbidities, some authors also add dimensional criteria and exclude the lesions that are greater than 5 cm (18). Recently some authors have extended the inclusion criteria and have treated with a robotic approach patients with advanced stages, as clinical IIIA stage after neoadjuvant therapies (39), or have performed sleeve lobectomy or robotic bronchoplastic upper lobectomy (40).

A review conducted by Kent *et al.* (41) collecting data from 33,095 patients treated with open, VATS and robotic approach in eight countries between 2008 and 2010, has shown that in “high-volume surgeons” robotic lobectomy is associated with a reduction in mortality, length of stay and overall complication rate compared with thoracotomy. Robotic lobectomy is also associated with a statistically significant reduction in mortality compared with VATS lobectomy.

As regards as the quality of life (QoL), Cerfolio *et al.* (30) firstly reported an analysis on thoracic robotic surgery patients that shows a significantly higher average mental QoL score 3 weeks postoperatively compared to open surgery.

Louie and colleagues (11) declared that patients operated with robotic-assisted surgery used fewer painkillers and returned to daily life sooner than when compared with VATS. A recent study by Kwon *et al.* (42) has shown no significant difference in acute and chronic postoperative pain between VATS and RATS. Interestingly patients who underwent robotic surgery felt that the robotic approach affected positively their pain, indicating an important difference between real and perceived pain.

A recent study published by Park *et al.* (43) compared post-operative data and survival outcomes of patients treated with lobectomy after induction chemotherapy using minimally invasive approaches (VATS or robotic procedures) or thoracotomy. The results show a similar OS and DFS between the two groups, suggesting the feasibility of using minimally invasive approaches, following induction therapy, to treat selected locally advanced stages of NSCLC.

Doubtlessly, the use of robotic system in thoracic surgery is still evolving as well as its indications and applications.

Moreover, several studies suggest that perioperative outcomes, including postoperative complications, are similar between robotic and conventional surgery (44).

Conclusions

Robotic surgery for lung lobectomy is feasible, safe, provides several improvements both for the patient (mainly in terms of higher rates of lymph nodal upstaging with less operative morbidity) and for the surgeon (advanced features of robotic platform and reduced learning curve) when compared to open and VATS approach in specialized centres (45).

Regarding the most discussed aspect of robotic procedures, its high capital and running costs, we believe that a management's strategy based on high surgical volumes, complex procedures and standardization of technique could reduce the costs of robotic procedures.

Therefore, taking into account what has been said, the right question to ask should be: "why not"?

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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